

MUNICIPAL WASTE COMBUSTION ASH: TESTING METHODS,
CONSTITUENTS AND POTENTIAL USES

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INTRODUCTION

This paper focuses on the content of combined ash, which represents the non-combustible portion of municipal solid waste. The term "ash" refers to all the solid residue streams of a municipal solid waste combustion system. This included: the bottom ash (approximately 85 to 95 percent of the total), also referred to as "clinker"; ash that collects on boiler, superheater and economizer tubes often referred to as "soot"; ash that is removed from the flue gas via the boiler passes, and the fly ash collected by the air pollution control equipment. The last type of ash is a combination of the solid material, as well as the reacted and unspent reagent from the acid gas scrubbers, that is collected after reaction in the scrubbers by the particulate collection equipment (e.g., the fabric filter or electrostatic precipitator). Bottom ash mainly comprises bottles, cans, auto parts, broken appliances and a myriad of other things that do not lend themselves to complete combustion. Fly ash originates from the ever-present fraction of inorganic compounds in paper, wood, plastic, rubber and food wastes. For example, there are clays in papers, stabilizers in plastics, pigments in printing, inks and mineral salts in vegetables and other products. In other words, the constituents that comprise the two types of ash represent the unavoidable, inorganic, by-products of everything that is thrown away.

By volume, the ash is approximately one-tenth to one-twentieth of the original incoming municipal solid waste. By weight, it represents approximately one-fourth of the original amount. It is much denser than raw solid waste and takes up much less space for ultimate disposal.

ENVIRONMENTAL BENEFITS OF COMBUSTING SOLID WASTE

Volume reduction, converting large amounts of solid waste material into smaller volumes, is a basic environmental protection practice that has been used for thousands of years. Many federal solid waste regulations are based on this premise and it has been a preferred solid waste management option for more than a century. Unfortunately, despite successful reduction and recycling programs, the United States will still need to combust the remainder of the waste stream.

Combusting municipal solid waste and converting it into energy has three basic purposes. First and foremost, the high temperatures accomplish sterilization and deny food and habitat

to disease vectors such as rats and flies. Secondly, volume reduction is successfully accomplished. And, thirdly, useful energy is captured. Throughout history, municipal solid waste was combusted to control disease and reduce volume. Up until the 1960s, open dumps were often set afire as a method of disease (vector) control and to make room for more garbage. Adverse repercussions such as brush fires, rat migration, air pollution, and worker fatalities led to public health problems that made open burning unsafe. However, burning municipal solid waste in a carefully-controlled furnace and managing ash efficiently can satisfy the original objectives without causing environmental harm. While volume reduction to reduce the burden of final waste disposal is essential, combustion can also convert municipal solid waste into energy that can be recovered.

The conversion of raw, unprocessed municipal solid waste into a smaller volume of ash results in long-term land preservation because ash disposal requires less space. There are many differences between disposing of raw municipal solid waste and landfilling ash.

Many environmental problems associated with municipal solid waste disposal can be reduced, mitigated, or eliminated with combustion. Landfilling of raw municipal solid waste generates odors, methane gas, and many other toxic and reactive gases. All these gases originate from the biological decomposition of organic matter. While odors are more annoying than dangerous, methane gas migration from poorly-designed and/or operated landfills has caused explosions in structures located nearby, resulting in millions of dollars of property damage and loss of life. By contrast, waste-to-energy ash is biologically inactive, generating no odors or explosive, toxic, or reactive gases from the landfill.

Potential ground water contamination can occur from any material disposed of in a landfill. This contamination is the result of moisture contained in the material, or rain, or surface water, infiltrating the material and leaching out toxic contaminants. Because organics predominate raw municipal waste, leachate from a landfill is also highly organic. In addition, it is acidic because of the biological activity within the landfill. The organic acids have a much greater potential to carry toxic compounds and elements into groundwater than the leachate from an ash landfill. In contrast, ash leachate that forms in small amounts (since infiltration through dense ash is very slight) contains only inorganic compounds -- salts and metals -- that do not easily travel through soil. By locating the landfill in the proper hydrogeological setting and/or by using liners and leachate collection systems, both leachates can be prevented from entering groundwater. Because ash leachate is predominantly inorganic, it can be contained with a simple lining system, and is not difficult to treat. Subsequently, the potential for groundwater contamination is much less than from a raw municipal solid waste landfill.

This has already been demonstrated in other parts of the world: Wurzburg, Germany; Marion County, Oregon; Denmark and

Sweden. In addition, the United States Environmental Protection Agency (EPA) is investigating ash leachate in a joint study with Marion County at the county's Woodburn monofill.

Dust represents another problem at landfills that can be reduced with combustion. Municipal solid waste is a very dusty material. When it is deposited in a landfill, without adequate controls, bits and pieces blow around. The compaction process requires driving large bulldozer-type vehicles over the municipal solid waste until it is compacted, which may increase dust generation. On the other hand, the semi-wet ash is delivered to the landfill and does not result in any fugitive dust. Since wet ash is so dense, it does not require much compaction. Consequently, very little airborne material is released into the environment during ash disposal.

Unlike ash residue, raw waste undergoes biological decomposition during the many years it remains placed in the landfill, volume reduction occurs gradually over time; it is an ongoing, slowly-evolving process. This continuous shrinkage causes the surface of the landfill to subside and requires extensive reworking of the soil. The subsidence also results in increased infiltration of rain water, which in turn produces more leachate. An ash landfill, however, becomes a stable mass within days of initial placement and requires only simple maintenance of the final cover. No subsidence whatever occurs. Modern waste-to-energy facilities reduce the volume of material and mitigate the potential public health problems associated with the ongoing land disposal of municipal solid waste.

PHYSICAL AND CHEMICAL PROPERTIES OF ASH

Unprocessed municipal solid waste contains varying percentages of inert materials that eventually become the ash or solid residues upon combustion in a resource recovery facility.

The volume reduction achieved by combustion increases the concentration of the metals in the ash versus the unburned municipal solid waste. The total amount of metals, however, have not increased. The increase in concentration cannot be any higher than the weight reduction (that is a 4-to-1 weight reduction of waste to ash, or 80 percent, increases concentration by a factor of five). Regardless of whether it is municipal solid waste that is landfilled, or ash from a resource recovery facility, the total amount of metals going in will remain the same. No data is available to suggest that the combustion process changes the properties of the metals to make them any more dangerous. On the contrary, leachate data from raw solid waste landfills suggests higher metal mobility because of biological activity and the presence of organic acids. From the available data on ash collected by Ogden Martin, the following list shows average metal concentrations in categories of major, minor and trace constituents:

METALLIC ASH CONSTITUENTS

<u>MAJOR</u>	<u>%</u>	<u>MINOR</u>	<u>%</u>	<u>TRACE</u>	<u>%</u>
Aluminum	3	Copper	0.1	Arsenic	0.003
Calcium	8	Lead	0.2	Barium	0.05
Iron	10	Manganese	0.6	Cadmium	0.003
Sodium	6	Molybdenum	0.1	Chromium	0.02
Silica	30	Potassium	0.4	Mercury	0.0006
		Titanium	0.7	Selenium	0.004
		Zinc	0.3	Silver	0.0006

In addition to the metals listed above, ash contains many other elemental compounds that make up the bulk of the material. Oxygen, sulfur, chlorine, which occur as oxides and sulfates, and chlorides account for more than 30 percent of the ash. There are also trace elements that can be detected at the lowest detection levels of modern analytical chemistry. This is also true of organic compounds, other than unburned or fixed carbon.

Based on an average of available data, the physical properties of ash can be tabulated as follows:

<u>Density</u>	one or two tons per cubic yard
<u>Specific gravity</u>	approximately one to three
<u>Moisture</u>	15% to 25%
<u>Grain Size</u>	10% similar to clay
	40% similar to sand
	30% similar to gravel
	20% larger than gravel
<u>Permeability</u>	10^{-3} to 10^{-4} cm/sec as landfilled
<u>Texture</u>	Wet concrete-like or wet sand and gravel-like

ASH MANAGEMENT AT AN OPERATING FACILITY

The Martin GmbH mass-burn design encompasses the closed-system concept to handle the process residue streams so that no employees, visitors or nearby residents will be exposed to airborne dust. All hoppers from the boiler to the air pollution control device have sealed, air-locked valves that transfer the fly ashes and/or dry scrubber reagent and reaction products to sealed screw or drag conveyors. In turn, these conveyors deliver all of the combined fly/bottom ash stream to the sealed discharger at the lower end of the furnace; just below the level where the bottom ash drops off the stoker grate.

As the bottom ash falls down the ash discharger chute into the quench water bath, the fly ash is captured, moistened and combined with the bottom ash before it is hydraulically discharged by a ram. The ram extrudes and dewater the ash prior to dropping it on the conveyor system. At this point, the ash has the consistency of wet concrete.

As it moves outside the boiler building, an enclosed conveyor transfers it to the ash storage building or another area to await transfer to covered, water-tight trucks or containers for eventual utilization or landfill burial. At any point, where the

employees or the public may be exposed, the ash system is either sealed or the ash moistened and enclosed in a building or conveyor.

ASH CHARACTERIZATION

Since the state environmental regulatory agencies have difficulty accurately predicting the potential adverse effects of burying waste, these governmental agencies typically have a two-pronged approach to the problem. Specific types of wastes, with high potential for causing environmental harm, are listed as "hazardous".

Secondly, regarding other wastes including ash, these agencies have established four broad characteristics to use in identifying waste that must be managed as "hazardous waste". The characteristics include ignitability, corrosivity, reactivity, and extraction procedure toxicity. This last characteristic is often applied to municipal waste combustion ash. The EP toxicity characteristic is determined by a devised laboratory test that attempts to mimic the landfill environment and disposal scenario of five percent unknown waste and 95 percent raw municipal waste in an unlined landfill.

Many problems occur with tests that take a small sample of waste, subject it to a laboratory analysis and then use the results to predict how larger quantities of hypothetical waste will really behave. For example:

- o How do you obtain representative samples?
- o How so you prepare these samples for laboratory analysis?
- o What type of test is most appropriate for the manner in which the waste will be managed?
- o How should varying results be interpreted?

Researchers in the waste management field have proposed additional tests that may be more appropriate. Currently, however, the ultimate test is one of sampling the actual leachate/groundwater from the managed (or mismanaged) land disposal unit.

The EP Toxicity test is the current test method employed by the EPA to determine if an unknown waste that may be subject to leaching in a landfill should be managed as a "hazardous waste". The Toxic Characteristics Leaching Procedure (TCLP) and other tests have also been proposed (published in the Federal Register and implemented for certain regulations as the land ban for certain hazardous wastes). Indeed, after much consideration, some agencies have eliminated or exempted waste-to-energy ash from laboratory testing.

Before considering what test should be used for regulatory or research purposes, a method must be available to obtain a representative sample. One cannot obtain an accurate sample by simply "grabbing" a small portion of the ash residue from a resource recovery facility, test it and declare that it is "hazardous". There is a very deliberate and detailed sampling procedure mandated by Section 1 of SW-846 (Test Methods for

Evaluating Solid Waste: Physical/Chemical Methods, U.S. EPA, Publication #SW 846, July 1982 as amended). Only by following these guidelines can one attempt to obtain representative ash samples and conclude within a certain degree of confidence, that the ash does or does not exhibit the characteristic of EP Toxicity, that it is hazardous by the TCLP, or by any other leaching procedure.

Even when Section 1 is closely followed and an extensive sampling program is performed, it may not necessarily provide representative samples. To adequately state the results within a 90 percent confidence limit, the number of samples cannot be determined until all the results of the samples are analyzed statistically. After following the sampling guidelines in SW-846, a difficult task of sample preparation must be applied.

The preparation methods in SW-846 result in the collection of many samples each weighing 50 to 100 pounds. These must be reduced in size to pass through a nine millimeter sieve. Typically, this step has been omitted in most ash sampling programs. The samples are usually screened and the subset of the sample, which passes through the nine millimeter screen, is the portion subjected to laboratory analysis. This, however, results in an unrepresentative sample in violation of the procedures in SW-846. Furthermore, some laboratories have failed to maintain the sample's moisture content or have completely dried the samples to ease preparation.

Once a representative sample is obtained, there are many laboratory tests that can be performed to collect data about it. This data is then used to determine leaching characteristics. Different official procedures require different tests for various characteristics that the ash exhibits. These tests include:

1. Percent Moisture
2. Particle Size and Structural Integrity
3. pH
4. Selected Anions (negatively-charged ions) and Cations (positively-charged ions)
5. Total Metals
6. Organic and Carbonaceous Material
7. Leaching or Extraction Tests, such as the EP Toxicity Test, the TCLP Test, a De-Ionized Water Leaching Test, a Solid Waste Leaching Procedure Test or Column or Lysimeter Tests

The extraction fluids are analyzed by atomic absorption or inductively-coupled argon plasma (ICAP). The analytical data are then examined for quality assurance/quality control and treated statistically to determine the results and confidence limits.

As rigorously as possible, OMS has followed the procedures in Volume 40 C.F.R. 261.24 and SW-846 in sampling and analyzing the ash from its operating facilities located in: Tulsa, Oklahoma; Marion County, Oregon; Hillsborough County, Florida; Bristol, Connecticut and Alexandria, Virginia. The ash did not exhibit the characteristic of hazardous waste in any instance.

The TCLP which is under development appears to be more consistent in yielding results. Sample collection and preparation problems are the same as with the EP (grinding portions of the ash that will not break down in the landfill). Consequently, like the EP, the results never represent behavior in the real environment because acid is poured through the ash, rather than dripped through it, over an extended period of time. Although the consistency of the data resulting from leachate procedures in the EP toxicity test have been improved with the TCLP, neither test produces data that simplifies what actually leaches from ash. A more accurate procedure for determining leaching characteristics would involve testing the actual leachate from an ash fill, especially a monofill that contains only waste-to-energy ash residue.

Test data for ash residue from OMS plants has been submitted to the EPA and state regulatory agencies. Lead and cadmium represent the only metals that occasionally show levels higher than the regulatory threshold in some limited samples. To simplify the following discussion, only lead will be addressed. When presenting the EP Toxicity or TCLP data, the value that is important is the upper limit of the confidence level. It is this value that is compared to the regulatory threshold and not individual sample values, even if they exceed the regulatory threshold. The most recent testing of the ash at Tulsa shows the following results for the upper band of the confidence limit on three separate analyses for EP toxicity and are for TCLP:

	<u>EP Toxicity</u>	<u>TCLP</u>	<u>Regulatory Threshold</u>
Lead (mg/l)	2.8	3.0	5.0

for the upper bound of the confidence limit. Of course, this means the average values were actually less.

For Marion County, a comprehensive testing program was performed in November 1986 during the facility's energy and capacity tests. The Marion County data is particularly significant because this facility is the first in the United States using a dry scrubber and high efficiency particulate control equipment (fabric filter baghouse) on a resource recovery facility. The data from Marion County's ash yielded the following results for the upper bound of the confidence limit on three separate analyses for EP toxicity and one for TCLP:

	<u>EP Toxicity</u>	<u>TCLP</u>	<u>Regulatory Threshold</u>
Lead (mg/l)	3.4 to 4.9	0.9	5.0

The tests conducted on the Bristol, Connecticut, facility, which has the same air pollution control configuration as the Marion plant, yielded similar test results. The upper bound of the confidence limit for lead was 2.5 mg/l.

OMS has performed, or has cooperatively studied with regulatory agencies, other tests on the ash from its facilities. With regard to the EP Toxicity organic substances, the levels are below the detection limit. Portions of the ash (i.e., the fly

ash) were analyzed by the EPA and determined to contain among the lowest levels of dioxin ever found in fly ash. These extremely low levels correspond to the very low levels of dioxin emissions achieved from the Martin GmbH stoker combustion system without any back-end pollution control, as well as from the stack gases with pollution control.

Limited leachate data is available from existing ashfills and sanitary landfills. The lead levels are lower for ash monofills, but results from both are far below the regulatory threshold of 5 mg/l. The data are as follows:

	Lead (mg/l)
Sanitary Landfill Leachate (Malcolm Pirnie)	0.2 to 1.0
Ashfill Leachate (Malcolm Pirnie)	<0.05 to 0.13
Wurzburg Ash Monofill Leachate	0.002 to 0.05
Sanitary Landfill Leachate (Malcolm Pirnie)	0.2 to 1.0
Ashfill Leachate (Malcolm Pirnie)	<0.05 to 0.13
Wurzburg Ash Monofill Leachate	0.002 to 0.05
*Marion, Ore. Ash Monofill Leachate	0.1 to 0.6
Scandinavian Monofill Leachates	0.001 to 0.1
**EPA Data (Four Sites)	<0.005 to 2.92

*Oregon Department of Environmental Quality

**U.S. Environmental Protection Agency data for Four Anonymous Sites

Measurements for lead and the seven other heavy metals in leachate from a landfill, in which both ash and raw solid waste have been placed (co-disposal), are well below the regulatory threshold(s), and have remained low over time. These lead levels were measured for the 1983-1987 testing of this co-disposal landfill leachate (in mg/l: 0.10, 0.19, 0.06, 0.33 and 0.12). When ash is buried with unprocessed municipal solid waste, the collected leachate still has a very low lead level.

More importantly, data recently collected by the U.S. EPA indicate that proper monofilling of ash has a negligible impact on the environment. The EPA has initiated a long-term study at the Marion County, Oregon, ash monofill. The first year's data show the leachate contained from 0.011 to 0.025 mg/l of lead. To determine if fugitive ash is a problem, soil samples were taken from around the monofill. The lead content of the soil both upwind and downwind of the facility contained 0.01 ppm of lead. Fifty-three (53) ppm lead was detected in the soil along Interstate 5, a few hundred meters east of the site. Background sample of soil east of the Interstate and far west of the facility showed levels of lead in the range of 0.014 to 0.017 ppm.

The EPA also tested for dioxins and furans in the soil around the monofill. The results were similar to tests conducted for lead. No differences between upwind, downwind, and background. The highest levels detected were along Interstate 5.

THE REGULATORY STATUS OF ASH

Because of the changing definition of "hazardous" waste, the regulatory status of municipal solid waste combustion ash has

been subject to debate over the past ten years. Prior to the Resource Conservation and Recovery Act of 1976 (RCRA), ash was primarily regulated by individual states or local jurisdictions as municipal solid waste. It was often approved as cover material for municipal solid waste sanitary landfills.

With the implementation of RCRA and the development of the federal hazardous waste management program, waste classification took on a new meaning. Congress and EPA split up the universe of waste into two categories. Those wastes, subject to management under Subtitle C of RCRA (hazardous wastes), and wastes subject to management under Subtitle D (non-hazardous wastes). Household waste and the ash residue from processing household waste were specifically excluded from Subtitle C.

This meant that household waste and incinerator ash was non-hazardous by definition. Since municipal solid waste, designated for a resource recovery facility, represents a combination of household waste and non-hazardous commercial and industrial waste, exclusion under the federal hazardous waste rules (Subtitle C) was thought to be unnecessary and therefore unavailable. Consequently, it became a requirement for the owners/operators of municipal solid waste combustion facilities to determine if their ash exhibited a hazardous waste characteristic by this difficult and onerous testing method.

When Congress enacted the Hazardous and Solid Waste Amendments of 1984, this regulatory difference between household waste and municipal solid waste ash was clarified. In this law, the ambiguous definition of "household waste" was clarified. The law states that, if a facility takes only household and non-hazardous commercial and industrial waste and has a program to prevent Subtitle C hazardous waste from being accepted, it is not deemed to be generating, treating or otherwise managing hazardous waste. In other words, the ash would not be subject to management as a hazardous waste, and testing to determine its regulatory status would not be required.

When EPA placed the law into the Code of Federal Regulations (CFR), they did not interpret it in the same way as Congress intended. EPA stated that, if the ash was tested and exhibited the characteristic of a hazardous waste, it had to be managed as such. This position has caused a great deal of confusion. If it exhibits a characteristic of hazardous waste, is the ash exempt from requirements to be managed as hazardous since it represents the by-product of municipal household waste? Or, is it to be managed as a solid waste in all cases? EPA is presently re-evaluating its decision, developing a new series of characterization tests to determine the regulatory status of ash, and developing environmentally-sound design criteria for ash burial.

Numerous states have taken similar positions. New York, Massachusetts, Tennessee and others have stated publicly that they believe the congressional clarification applies to the combined ash. The state of Oregon, well-known for some of the toughest environmental standards in the United States, believes the present testing requirements in 40 CFR 261 (which stipulates

performance of the EP Toxicity test and other leaching procedures for hazardous wastes) are invalid for determining ash characteristics and should not be used to determine regulatory status. Other states are taking the same position. All state and federal regulatory agencies that are addressing this subject believe that efficient ash management is essential regardless of the outcome of various characterization tests.

There is no environmental exclusion from testing ash, but what is considered "efficient management" varies across the board nationwide. Consequently, regulators are developing proper ash management criteria for compliance. These criteria focus on prevention of groundwater contamination through the use of lined landfills. While monofilling ash is the most desirable option, it is probably an overly stringent requirement considering that it is unlikely that co-disposal leachate would penetrate a well-designed system, particularly one which incorporates a leachate collecting system as well as the required linings.

Both Congress and the EPA are in the process of further clarifying the regulatory status of ash and developing management standards. In numerous proposed bills, Congress has clearly stated that ash should be managed as a Subtitle D (non-hazardous) waste. In addition, all the bills require some type of lining, leachate collection, and groundwater monitoring systems for ash disposal. It is doubtful that these bills will be voted into law this session of Congress, but legislation as important as this should move in the spring of 1989.

EPA has released draft guidance on the handling, transport, storage, and disposal of ash. This guidance includes recommendations that ash containers and transport vehicles be leakproof and provided with tight coverings; that groundwater monitoring be performed at all ash disposal facilities. These liners and disposal recommendations are as follows:

- o For fly ash disposed separately, disposal should be at a monofill with a double liner system.
- o For combined ash or bottom ash, disposed of in a monofill, either a composite liner or a clay liner with special environmental or operating features should be used.
- o For combined ash or bottom ash codisposed with garbage, a double liner or a composite liner, with pre-disposal ash treatment or source separation to reduce metals content prior to combustion is the preferred method.

ASH UTILIZATION

As discussed previously, ash contains many valuable metals and the non-metallic fraction has properties very similar to sand and gravel. These characteristics lend themselves to potential economic benefits. Ferrous and non-ferrous metal recovery using magnets, screens and other mechanical processes is used at many municipal solid waste combustion facilities worldwide. The techniques for recovery of the larger metallic components (e.g., greater than one inch) are well developed. Metals are not recovered on an industry-wide scale in the United States because

of depressed scrap metal markets (i.e., installation and operation of metal recovery equipment is dependent on local scrap metal markets). OMS investigates the local scrap markets to determine the economic viability of metals recovery from all its facilities as they enter commercial operation.

There are many metals in the ash that could only be recovered through complex and laborious processes. Metals such as cadmium, lead, zinc, copper, silver and gold are recoverable by using chemical techniques similar to those used in the minerals industry. OMS is currently investigating the feasibility of recovering these metals from the ash with various industrial concerns and research laboratories.

The major component in the ash is the inert, non-metallic fraction. Because the properties are similar to traditional aggregates, ash is commonly used as a substitute for conventional aggregate in Europe. In the mid-1970s, the Department of Transportation (DOT) researched the potential for use in the construction and maintenance of highways. Today, Marion County is pursuing the same option. In Europe, bottom ash is often used in asphaltic paving material and combined bottom and fly ash in concrete. Screened bottom ash is also used as road bed and common fill material. Perhaps, the best use of ash is as aggregate in Portland cement concrete. Municipal solid waste combustion ash has excellent properties for use in concrete itself; it is pozzolanic, which is to say it forms a weak cement-like matrix. This inherent property could be of interest to concrete block manufacturers. OMS is working with two universities to develop proper screening techniques and mixture proportions for cement blocks. Leachability of metals from the blocks will be an important issue that will require resolution before they are widely manufactured. In addition, OMS and one university are determining the likelihood of leachability of metals from the completed blocks.

There are many potentials for the use of combined ash. While the technical problems associated with the various utilization scenarios can be resolved, the institutional problems are more difficult to address (i.e., markets for the metals and public acceptance of the ash as aggregate). Lessons can be learned from Europe and Japan and other waste product utilization programs. In Japan, ash residue is used to make artificial reefs and man-made islands. Thus far, metals have not entered the food chain and subsequently pose no significant risk to aquatic life or human beings. While the United States may not necessarily need ash islands or reefs, there are many other potential uses that would fulfill material needs in the construction, manufacturing or chemical industries.

SUMMARY

Ash is the remaining incombustible residue representing five to ten percent by volume and 15-20 percent by weight of the municipal solid waste stream. It is a biologically inert, dense material that can be managed in a more environmentally sound manner than raw solid waste. Present testing methods do not

adequately simulate what occurs when ash is placed into a controlled landfill unit. As indicated by leachate data from actual ash fills, potential ground or surface water contamination from well-managed ash disposal units does not appear to be a problem. Before uses of combined ash can reach their fullest potential, public awareness and a better understanding of resource recovery ash characteristics is necessary. This can only be achieved through governmental leadership at state and local levels, where community education is most effective.